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Neptune.

1896.	R. A. H. M.	Declination. ° ′	Rises. H. M.	Transits. H. M.	Sets. H. M.
Feb. 1.	4 57	+21 12	12 52 P.M.	8 11 P.M.	3 30 A.M.
11.	4 57	+21 12	12 12	7 31	2 50
21.	4 57	+21 12	11 33 A.M.	6 52	2 11
Mar. 2.	4 57	+21 13	10 54	6 13	1 32

Eclipses of *Jupiter's* Satellites, P. S. T.

The eclipses are to be seen near the right limb of the planet, a little below the line of the belts, as seen in an inverting telescope.

		H. M.			H. M.
II, R,	Feb. 2.	10 30 P. M.	I, R,	Feb. 16.	2 45 P. M.
I, R,	4.	5 24 A. M.	II, R,	17.	3 41 A. M.
III, R,	5.	3 42 P. M.	III, R,	19.	11 42 P. M.
I, R,	5.	11 53 P. M.	I, R,	20.	3 42 A. M.
IV, R,	6.	4 17 P. M.	II, R,	20.	4 59 P. M.
I, R,	7.	6 21 P. M.	I, R,	21.	10 11 P. M.
II, R,	10.	1 6 A. M.	I, R,	23.	4 40 P. M.
III, R,	12.	7 42 P. M.	III, R,	27.	3 42 A. M.
I, R,	13.	1 47 A. M.	II, R,	27.	7 34 P. M.
I, R,	14.	8 16 P. M.	I, R,	29.	12 6 A. M.

HELIUM, ASTRONOMICALLY CONSIDERED.

By Edwin B. Frost.

Scientific discoveries seldom come singly. The mastering of one problem of nature commonly suggests new modes of attacking other problems, and often contains in itself the key to their solution. Perhaps it is quite as frequently the case that new discoveries follow incidentally, it may be, in the researches for completing the original discovery, or in the revived interest in subjects previously supposed to be exhausted for research with known methods.

So it was that the brilliant discovery in 1894, by Lord Rayleigh and Professor Ramsay of the gaseous element, argon, after very long and painstaking researches, led incidentally to the detection of terrestrial helium by the latter of these distinguished investigators — a discovery of far more astronomical importance than that of argon itself. The renewed interest in the study of gases occluded in minerals may very possibly soon bring to light still other elements.

In a paper sent to the Royal Society on March 26, 1895, and read a month later, Professor RAMSAY recites the circumstances leading to the discovery of the missing element, helium, so well known as a constituent of the Sun and certain stars, but hitherto not isolated on the Earth. We quote from that paper:* "In the course of investigations on argon, some clew was sought for, which would lead to the selection of one out of the almost innumerable compounds with which chemists are acquainted, with which to attempt to induce argon to combine. A paper by W. F. HILLEBRAND, 'On the Occurrence of Nitrogen in Uraninite, etc.' (*Bull. of the U. S. Geological Survey*, No. 78, p. 43), to which Mr. MIERS kindly directed my attention, gave the desired clew. In spite of HILLEBRAND'S positive proof that the gas he obtained by boiling various samples of uraninite with weak sulphuric acid was nitrogen (p. 55) — such as formation of ammonia on sparking with hydrogen, analysis of the platinichloride, vacuum-tube spectrum, etc.,—I was skeptical enough to doubt that any compound of nitrogen, when boiled with acid, would yield free nitrogen. The result has justified the skepticism.

"The mineral employed was clèveite, essentially a uranate of lead, containing rare earths. On boiling with weak sulphuric acid, a considerable quantity of gas was evolved. It was sparked with oxygen over soda, so as to free it from nitrogen and all known gaseous bodies, except argon; there was but little contraction; the nitrogen removed may well have been introduced from air during this preliminary experiment. The gas was transferred over mercury, and the oxygen absorbed by potassium pyrogallate; the gas was removed, washed with a trace of boiled water, and dried by admitting a little sulphuric acid into the tube containing it, which stood over mercury. The total amount was some twenty cubic centimetres.

"Several vacuum-tubes were filled with this gas, and the spectrum was examined, the spectrum of argon being thrown simultaneously into the spectroscope. It was at once evident that a new gas was present along with argon.

"Fortunately, the argon-tube was one which had been made to try whether magnesium-poles would free the argon from all traces of nitrogen. This it did; but hydrogen was evolved from the magnesium, so that its spectrum was distinctly visible. Moreover, magnesium usually contains sodium, and the *D* line was also visible, though faintly, in the argon-tube. The gas from clèveite also showed hydrogen lines dimly, probably through not having been filled with completely dried gas.

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* *Proc. R. S.*, Vol. LVIII, 65–67, 1895; reprinted in *Nature*, Vol. LII, 7–8.

"On comparing the two spectra, I noticed at once that while the hydrogen and argon lines in both tubes accurately coincided, a brilliant line in the yellow, in the clèveite gas, was nearly, *but not quite*, coincident with the sodium line *D* of the argon-tube.

Mr. CROOKES was so kind as to measure the wave-length of this remarkably brilliant yellow line. It is 587.49 millionths of a millimeter, and is exactly coincident with the line D_3 in the solar chromosphere, attributed to the solar element which has been named *helium*."

The paper gave a further comparison between the spectrum of the argon-tube and the helium-tube, but, as later appeared, the presence of the argon lines in the helium-tube must have been due to the accidental introduction of air.

In the same number of the *Proceedings*, a note by Professor LOCKYER follows, in which he describes* the results he obtained, immediately after hearing of the discovery, by the process of heating *in vacuo* particles of uraninite, and photographing the spectrum of the resulting gas. A number of lines now known to have been due to impurities were thus registered, but the spectrum showed the chromospheric line at λ 4472, which, as LOCKYER stated, is "as important as D_3 itself, from the theoretical point of view, to students of solar physics."

Meanwhile, the spectrum of the new gas was being studied by numerous other spectroscopists, and CLÈVE published† THALEN'S visual but accurate measures of the wave-lengths of six lines, all well known in the solar chromosphere, namely: λ 6677, D_3, 5048, 5016, 4922, 4714. At the session of the Royal Society, on May 9th, two notes were presented by LOCKYER, in which he described the results of his experiments upon a number of minerals of the class of uraninite. From the variations in the occurrence and intensities of the different lines, both in the chromosphere and in the laboratory, LOCKYER considered the evidence to be strong that helium is a mixture, not a single element. A list was given of seventeen lines measured on photographs (from λ 3889 to λ 4580) of the spectra from eighteen minerals. Of these, all but five (those at λ 3889, 4026, 4144, 4389, 4471) now seem to have been due to impurities which could not well be avoided in the distillation method used.

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* Also, in *Nature*, Vol. LII, 8, 1895.

† *C. R.*, Vol. CXX, 834-835, (April 16th).

At the *séance* of the French Academy on May 20th, DESLANDRES communicated* the well-determined wave-lengths of twenty lines, including eleven of those already named, all of which have since been fully confirmed as belonging to the pure spectrum of helium. He also showed the numerous coincidences of these lines with those of the chromosphere, and cites the difference in their intensities in the chromosphere as evidence that what is called helium is a mixture or compound.

Thus far, however, the wave-length of the orange line had not been determined with the utmost accuracy that modern apparatus permits, and, doubtless, some skepticism still prevailed as to the absolute coincidence with D_3. The crucial test soon came, however, in a letter from Prof. RUNGE, dated at Hanover on May 16th, and published in *Nature* (Vol. LII, 128,) on June 6th. With Prof. PASCHEN, he photographed the concave-grating spectrum of clèveite, with iron for comparison, and found the orange line a *double*, a strong component at λ 5875.883, and a weak comparison at λ 5876.206 (ROWLAND'S standard value, without any mention of duplicity, being 5875.982). RUNGE, therefore, dissented from the conclusion that the line coincided with D_3, "*unless D_3 is shown to be double.*" This brought out a letter from Dr. HUGGINS (*Chem. News*, Vol. LXXI, 283, June 14, 1895,) affirming his conviction, based on earlier observations as well as special ones for the purpose, that the chromospheric D_3 is not double. He recalled that BELOPOLSKY (*Mem. Societá Spett. Ital.*, May, 1894,) had occasionally seen D_3 apparently rendered a double by the superposition of terrestrial lines, and raised the query: "May it be that the clèveite gas is the stuff giving rise to these terrestrial lines?" HALE,† however, obtained the opposite result; for, directly upon reading RUNGE'S note, he observed D_3 in the fourth order grating-spectrum of a very bright prominence, which luckily was on the limb at the time. A faint companion was at once detected on the less refrangible side of

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* *C. R.*, Vol. CXX, 1112–1114.

† *Astrophysical Journal*, Vol. II, 165–166.

D_3, at a distance which he measured (on June 20th and 21st) as 0.357 tenth-meters, a result differing by only 0.034 tenth-meters from that of RUNGE and PASCHEN. The duplicity of D_3 was soon confirmed by various possessors of powerful spectroscopes, and Dr. HUGGINS observed it a few weeks later under more favorable atmospheric conditions. The proof of the identity of D_3 was thus practically complete.

Additional lines of the spectrum of clèveite and other minerals were rapidly announced,—the important unidentified chromospheric line at λ 7065 by LOCKYER,* and another line in the red, at λ 7285 (more accurately 7282), by DESLANDRES.† Finally RUNGE and PASCHEN communicated,‡ July 11, to the Berlin Academy the results of their very accurate determinations of wave-lengths of lines in the spectrum of GEISSLER tubes containing gas extracted from a pure crystal of clèveite. They were able to explore the ultra-red spectrum with a bolometer, and there discovered two lines which they had been led to expect from theoretical reasons,—the rhythmical relations of the wave-lengths.

It is now ten years since BALMER announced that the wave-lengths of the lines of the principal series in the hydrogen spectrum can be expressed by the formula

$$\lambda = \lambda_0 \frac{m^2}{m^2 - 4}$$

where λ_0 is a constant wave-length, and m has successively the values 3, 4, 5, etc. Somewhat similar formulæ have been found by other investigators for numerous elements. The formula applying to helium was found by RUNGE and PASCHEN to be

$$\frac{1}{\lambda} = A - \frac{B}{m^2} - \frac{C}{m^4},$$

where A, B and C are constants. As they state: "A determines the end of the series toward which the lines approach for high values of m, but does not influence the difference of the wave-numbers of any two lines. B has nearly the same value for all the series observed, and C may be said to determine the spread of the series, corresponding intervals between the wave-numbers being larger for larger values of C. As B is approximately known, two wave-lengths of a series suffice to determine the constants *A* and *C*, and thus to calculate approximately the wave-lengths of the other lines. It was by this means that we succeeded in disentangling the spectrum of the gas in clèveite, and showing its regularity." As a result of their analysis they find six series of lines in the spectrum of the gas from clèveite, and they assign three series to each of what they call "constituents" of helium, their reasoning leading them to the conclusion that the gas is a mixture of two distinct elementary gases. The wave-lengths are as follows, two of the series being chiefly composed of double lines :

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* *Proc. R. S.*, Vol. LVIII, 192, dated May 28, 1895.

† *C. R.*, Vol. CXX, 1331-1333, June 17.

‡ Reprinted in *Phil. Mag.* Vol, XL, 297-302, September 1895.

HEAVIER CONSTITUENT (HELIUM PROPER).			LIGHTER CONSTITUENT.		
PRINCIPAL SERIES.	FIRST SUBORDINATE SERIES.	SECOND SUBORDINATE SERIES.	PRINCIPAL SERIES.	FIRST SUBORDINATE SERIES.	SECOND SUBORDINATE SERIES.
11220.			20400.		
3888.97	5876.206	7065.77	5015.73	6678.1	7281.8
3888.76	5875.883	7065.51	3965.08	4922.08	5047.82
3187.98	4471.85	4713.39	3964.84	4388.11	4437.73
3187.83	4471.66	4713.17	3613.89	4143.91	4169.12
2945.35	4026.52	4121.15	3613.78	4009.	4024.14
2945.22	4026.35	4120.98	3447.73	3927.	3936.1
2829.32	3819.89	3867.77	3354.7	3872.	3878.3
2829.16	3819.75	3867.61	3296.9	3834.	3838.2
2764.01	3705.29	3733.15	3258.3	3806.	3808.3 (?)
2763.91	3705.15	3733.01	3231.3	3785.	
2723.3	3634.52	3652.29	3213.4		
2696.5	3634.39	3652.15			
2677.1	3587.54	3599.			
	3587.42	3563.			
	3554.5	3537.			
	3530.6	3517.			
	3512.6	3503.			
	3498.7	3491.			
	3487.8	3482.			
	3479.2				
	3472.				
	3466.				
	3461.				

Nature for August 29th (Vol. LII, 428–430) reprints from the *Chemical News* of the preceding week an article by CROOKES, giving the wave-lengths of all the lines measured by him in the spectra of five samples of gas from different mineral sources. The lines include nearly all those given by RUNGE and PASCHEN, and a large number in addition, which would seem to be due to some other substance or substances contained in the minerals. Some of these lines have also been observed by LOCKYER, and may have an astronomical importance when their origin is more accurately located. In view of the different, and even antithetical, behavior of spectral lines of the same element under different conditions of electric tension, temperature, pressure, etc., opinion may for the present be reserved as to the correctness of the conclusion of RUNGE and PASCHEN regarding the compound character of helium, but it certainly would seem that the two spectra must correspond to two quite definite physical states of the radiating gas, if it be elementary. It will be recalled that argon gives two quite distinct spectra ; but the harmonic relations of argon lines have apparently not yet been investigated. In passing, it may be stated that as yet argon has no astronomical significance, as no lines of its spectrum have thus far been recorded in celestial spectra. According to the latest statement seen by the writer, RAMSAY does not, from the chemical point of view, accept the conclusion that helium has two constituents. With a proper reserve, however, it is for the present quite allowable to use the terms heavier and lighter constituent.

Helium (both constituents) has recently been detected as bubbling from certain springs in the Black Forest, in the Pyrenees, and elsewhere; so it must be more or less present with argon in the atmosphere. KAYSER considers that the faint helium lines seen by him in the spectrum of argon that had been prepared as carefully as possible are direct proof of its presence in the atmosphere at Bonn.

The density of helium has been found by CLÈVE to be 2.02, by RAMSAY to be 2.18, in terms of the density of hydrogen. It has not yet been possible to induce helium to enter into combination with other elements.

We have already alluded to the coincidences of the new helium lines with well-known chromospheric lines whose indentification had hitherto been doubtful, — especially, of course, λ 7066, D_3, and LORENZONI'S *f*, (which is the strong line at λ 4472), all of which are permanently present in the chromospheric spectrum. A large number of the ultra-violet chromospheric and prominence lines photographed by HALE and DESLANDRES are also doubtless coincident with helium lines. The singular fact that none of the helium lines are present as dark lines in the Sun, wherein the new lines only follow the example of D_3, still awaits a satisfactory explanation. It had formerly been inferred that D_3 did not occur as a dark line in any celestial spectrum, but dark D_3 was not long ago detected at the Lick Observatory, in *β Lyræ* by KEELER, and in *β* and *ε Orionis* by CAMPBELL.

In the spectra of the nebulæ helium is conspicuous, but the lines of the "heavier constituent" are far the more prominent—in a measure a confirmation of the correctness of the differentiation of the constituents. D_3 was discovered in the *Orion* nebula by COPELAND in 1886, and a faint line at λ 4476 in the following year. D_3 has since been observed by KEELER and by CAMPBELL in other nebulæ, and the latter has measured λ 4472 in several nebulæ. Every one of the lines of "helium proper" occurring within the limits of the known nebular spectrum up to λ 3700 can be readily identified with some line in the latter, while of the nineteen lines within these limits, assigned to the "lighter constituent," but six (those at λ 4923, 4388, 4169, 4144, 4009, and 3878) have been certainly recorded in nebulæ.

Our knowledge of stellar spectra of Type Ia does not seem to be especially affected by the discovery of terrestrial helium, as the dark lines of helium are not ordinarily visible in this type. However, the 4472 line has been photographed by SCHEINER in the spectra of the *Orion* stars δ, γ, and ζ, which are included in Class Ia, and *α Virginis*, *Algol*, *η Ursæ majoris*, and *β Tauri;* and λ 4388 (of the lighter constituent) is found in *α Virginis* and γ *Orionis*. Yet it is not to be inferred that helium may not be present in stars of this class, as also in stars at the solar stage (Class IIa), in which no lines of helium have yet been recorded. If we were only able to study the spectrum of the Sun as a whole, without examining the separate spectrum of the limb, we should not know that solar helium existed.

With spectra of Type Ib, however, the conditions are quite different from those of the two types just considered. Here the characteristic dark line, often called the "Orion line" from its occurrence in stars of *Orion* near the nebula, is at once located, after long baffling identification, as the strong helium line at λ 4472, which appears as a bright line in the nebula. This is quite in accord with the recent observations of dark D_3 in certain *Orion* stars of this class (in *β*, CAMPBELL, KEELER; in *ε*, CAMPBELL; in γ and ζ, FOWLER), although it had already been surmised that the substance producing the "Orion line" must be of a somewhat similar character to hydrogen. Of about fifty lines given by KEELER and by SCHEINER in the spectrum of *β Orionis*, some eleven are due to helium, both "constituents" being represented. A close physical connection is indicated between these stars of *Orion* and the great nebula, although the latest observations of CAMPBELL and KEELER do not confirm HUGGINS' photograph of bright lines in the spectra of the trapezium stars, as they are dark on their plates.

In stars of Class Ic, including β *Lyræ*, γ *Cassiopeiæ*, and *P Cygni*, helium predominates, its lines being more numerous in β *Lyræ* than even those of hydrogen. These two elements together characterize this star, and produce most remarkable shifting bands, with bright and dark components. The extraordinary complexity of the band in β *Lyræ* near hydrogen ζ (λ 3889) is at once explained as the result of the juxtaposition and probable overlapping of the two bands, one due to hydrogen and the other to helium. Orbital motions are evident in β *Lyræ*, and possibly occur in other stars of this class, which adds to their interest as being objects apparently in one of the earliest stage of development from the nebulæ.

As has been already said, helium lines have not been observed in spectra of the solar type, which only confirms the view that those stars are in almost the identical condition of our Sun.

It seems singular, however, that the WOLF–RAYET stars, of Class IIb, should not show helium more conspicuously. These stars have recently been very successfully studied by CAMPBELL, but of over fifty lines measured only four can be assigned to helium, namely: D_3, λ 4472, 4388, and 4026. The identification of most of the lines of these spectra must await further discoveries of terrestrial chemistry.

Laboratory helium adds something, however, to our knowledge of temporary stars; for quite a number of the important lines of *Nova Aurigæ* can now be assigned to it. Especially noteworthy is the strong line in the green, at λ 5016, whose wavelength was carefully determined by numerous observers. This is undoubtedly identical with the second line of the first series of the lighter constituent at λ 5015.7, and hence the idea of some must be abandoned that the line was really the chief nebular line (λ 5007) greatly displaced. Both helium constituents were present in the *Nova*, but the lighter was the more conspicuous. It is, however, quite remarkable that at the second apparition, when the spectrum had become nebular, only three of the helium lines were present, all very faint, although, as has already been stated, helium lines are abundant in the brighter nebulæ.

Helium does not manifest itself in stars of Classes IIIa and IIIb, as indeed could hardly be expected; for, with the increased absorption by the compounds which seem to form at the presumably low temperature of these stars, hydrogen and the lighter gases appear to retire. Helium lines might be looked for among the bright lines that flash out as the long-period variables of Class IIIa approach a maximum, but they do not seem to be present. Comets, meteors, and aurora alike give no spectroscopic testimony of helium, although its presence has been chemically detected by RAMSAY in a meteorite. With this ends the present record of helium as a constituent of celestial objects. First discovered in the Sun, it has eluded detection in our own planet for over a quarter of a century, but the logic of common origin and common chemical constitution of Sun and Earth has now been vindicated.

It is not too much to expect that the revived study of gases occluded in minerals will soon lead to the discovery of other substances or elements whose existence is thus far known to us only from the spectroscopic evidence of celestial objects. In particular, we ought next to hope for the enrollment among the family of terrestrial elements of the substances producing the corona line and the characteristic nebular lines.

DARTMOUTH COLLEGE, HANOVER, N. H., Nov. 18, 1895.

THE MOON,* BY THOMAS GWYN ELGER.

REVIEWED BY M. C. M. GAUDIBERT.

Since M. WEBB, many years ago, published in his well-known and highly appreciated book, *Celestial Objects for Common Telescopes*, his short but very suggestive treatise on the Moon, the study of the visible surface of our satellite has received such an impetus among an ever-increasing number of observers, that no slackness is perceptible even to the present day. This little work, also, came out about the time when MM. G. WITH and BROWNING placed in the hands of the public their deservedly celebrated telescopes with silvered mirrors, at such comparatively

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* The Moon, a full description and map of its principal physical features, by THOMAS GWYN ELGER, F. R. A. S. London, GEORGE PHILIP & SON, 1895. 8vo, pp. 173.